

83 Rec'd PCT/PTO 13 MAY 1997

FORM PTO-1390 (REV 10-93)		U.S. DEPARTMENT OF COMMERCE PATENT AND TRADEMARK OFFICE	ATTORNEY'S DOCKET NUMBER RSG 8379 US
TRANSMITTAL LETTER TO THE UNITED STATES DESIGNATED/ELECTED OFFICE (DO/EO/US) CONCERNING A FILING UNDER 35 U.S.C. 371			U.S. APPLICATION NO. (PCT/PTO) 087836309
INTERNATIONAL APPLICATION NO. PCT/EP96/03330	INTERNATIONAL FILING DATE 29 JULY 1996	PRIORITY DATE CLAIMED 3 AUGUST 1995	
TITLE OF INVENTION TEMPERATURE-MEASUREMENT INSTRUMENT WITH DIFFRACTIVE OPTICS			
APPLICANT(S) FOR DO/EO/US SCHMIDT, Volker			

Applicant herewith submits to the United States Designated/Elected Office (DO/EO/US) the following items and other information:

- ☒ This is a **FIRST** submission of items concerning a filing under 35 U.S.C. 371.
- ☐ This is a **SECOND** or **SUBSEQUENT** submission of items concerning a filing under 35 U.S.C. 371.
- ☒ This express request to begin national examination procedures (35 U.S.C. 371(f)) at any time rather than delay examination until the expiration of the applicable time limit set in 35 U.S.C. 371(b) and PCT Articles 22 and 39(1).
- ☒ A proper Demand for International Preliminary Examination was made by the 19th month from the earliest claimed priority date.
- ☒ A copy of the International Application as filed (35 U.S.C. 371(c)(2))
 - ☒ is transmitted herewith (required only if not transmitted by the International Bureau).
 - ☐ has been transmitted by the International Bureau.
 - ☐ is not required, as the application was filed in the United States Receiving Office (RO/US).
- ☒ A translation of the International Application into English (35 U.S.C. 371(c)(2)).
- ☒ Amendments to the claims of the International Application under PCT Article 19 (35 U.S.C. 371(c)(3))
 - ☐ are transmitted herewith (required only if not transmitted by the International Bureau).
 - ☐ have been transmitted by the International Bureau.
 - ☐ have not been made; however, the time limit for making such amendments has NOT expired.
 - ☒ have not been made and will not be made.
- ☐ A translation of the amendments to the claims under PCT Article 19 (35 U.S.C. 371(c)(3)).
- ☐ An oath or declaration of the inventor(s) (35 U.S.C. 371(c)(4)).
- ☐ A translation of the annexes to the International Preliminary Examination Report under PCT Article 36 (35 U.S.C. 371(c)(5)).

Items 11. to 16. below concern document(s) or information included:

- ☒ An Information Disclosure Statement under 37 CFR 1.97 and 1.98.
- ☐ An assignment document for recording. A separate cover sheet in compliance with 37 CFR 3.28 and 3.31 is included.
- ☐ A FIRST preliminary amendment.
☐ A SECOND or SUBSEQUENT preliminary amendment.
- ☐ A substitute specification.
- ☐ A change of power of attorney and/or address letter.
- ☒ Other items or information:
 PCT/IPEA/409 5 pgs
 PCT/IB/304 1 pgs
 PCT/IB/308 1 pgs
 PCT/ISA/210 5 pgs
 PCT/RO/101 3 pgs

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 I hereby certify that this paper or fee
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Carole L. Williams
 Carole L. Williams

U.S. APPLICATION NO (if known, see 37 CFR 1.5)		INTERNATIONAL APPLICATION NO PCT/EP96/03330		ATTORNEY'S DOCKET NUMBER RSG 8379 US	
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17. <input checked="" type="checkbox"/> The following fees are submitted: BASIC NATIONAL FEE (37 CFR 1.492(a)(1)-(5)): \$910.00 Search Report has been prepared by the EPO or JPO \$880.00 International preliminary examination fee paid to USPTO (37 CFR 1.482) \$680.00 No international preliminary examination fee paid to USPTO (37 CFR 1.482) but international search fee paid to USPTO (37 CFR 1.445(a)(2)) \$750.00 Neither international preliminary examination fee (37 CFR 1.482) nor international search fee (37 CFR 1.445(a)(2)) paid to USPTO \$1010.00 International preliminary examination fee paid to USPTO (37 CFR 1.482) and all claims satisfied provisions of PCT Article 33(2)-(4) \$94.00 <div style="text-align: right;">ENTER APPROPRIATE BASIC FEE AMOUNT =</div>				CALCULATIONS PTO USE ONLY <div style="border: 1px solid black; padding: 5px;"> <div style="display: flex; justify-content: space-between;">\$910.00</div> </div>	
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Surcharge of \$130.00 for furnishing the oath or declaration later than <input type="checkbox"/> 20 <input type="checkbox"/> 30 months from the earliest claimed priority date (37 CFR 1.492(e)).				\$	
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CLAIMS	NUMBER FILED	NUMBER EXTRA	RATE		
Total claims	14 - 20 =	0	X \$22.00	\$	00
Independent claims	1 - 3 =	0	X \$78.00	\$	00
MULTIPLE DEPENDENT CLAIM(S) (if applicable) YES			+ \$250.00	\$	260.00
TOTAL OF ABOVE CALCULATIONS =				\$	1,170.00
Reduction of 1/2 for filing by small entity, if applicable. Verified Small Entity Statement must also be filed (Note 37 CFR 1.9, 1.27, 1.28).				\$	
SUBTOTAL =				\$	1,170.00
Processing fee of \$130.00 for furnishing the English translation later than <input type="checkbox"/> 20 <input type="checkbox"/> 30 months from the earliest claimed priority date (37 CFR 1.492(f)).				\$	
TOTAL NATIONAL FEE =				\$	
Fee for recording the enclosed assignment (37 CFR 1.21(h)). The assignment must be accompanied by an appropriate cover sheet (37 CFR 3.28, 3.31). \$40.00 per property				\$	
TOTAL FEES ENCLOSED =				\$	1,170.00
				Amount to be:	\$
				refunded	\$
				charged	\$

a. ☒ A check in the amount of \$ 1,170.00 to cover the above fees is enclosed. Check No. 12928

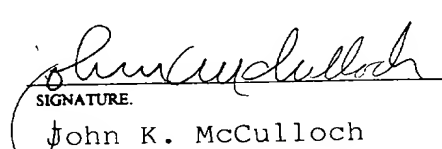
b. ☐ Please charge my Deposit Account No. _____ in the amount of \$ _____ to cover the above fees. A duplicate copy of this sheet is enclosed.

c. ☒ The Commissioner is hereby authorized to charge any additional fees which may be required, or credit any overpayment to Deposit Account No. 12-0755. A duplicate copy of this sheet is enclosed.

NOTE: Where an appropriate time limit under 37 CFR 1.494 or 1.495 has not been met, a petition to revive (37 CFR 1.137(a) or (b)) must be filed and granted to restore the application to pending status.

SEND ALL CORRESPONDENCE TO:

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 SIGNATURE
 John K. McCulloch
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 REGISTRATION NUMBER

Claims

1. Device for temperature measurement comprising
 - a) a detector (1) for receiving heat radiation (3) emanating from a measurement spot (2a) on an object of measurement (2),
 - b) an optical system (4) for imaging the heat radiation emanating from the measurement spot onto the detector (1)
 - c) and a sighting arrangement (5) for identifying the position and size of the measurement spot (2a) on the object of measurement by means of visible light (6)'

characterised in that

- d) the sighting arrangement (5) has a diffractive optical system ~~(holographic element 5b)~~ to produce a light intensity distribution.

2. Device as claimed in Claim 1, characterised in that the sighting arrangement (5) also has at least one additional refracting and/or reflecting optical element (5c, 5'c).

3. Device as claimed in Claim 1, characterised in that the diffractive optical system is formed by a holographic element (5b).

4. Device as claimed in Claim 1, characterised by such a design of the diffractive optical system that the light intensity distribution on the object of measurement (2) forms an annular marking (3a; 3b).

5. Device as claimed in Claim 4, characterised in that the

light intensity distribution is formed by at least two circular markings (3f, 3g, 3h) which are arranged concentrically with respect to one another.

6. Device as claimed in Claim 4 or 5, characterised in that the light intensity distribution also has a further marking (3c) which represents the centre of the measurement spot.

7. Device as claimed in Claim 1, characterised by such a design of the diffractive optical system that the light intensity distribution on the object of measurement (2) forms a cross-shaped marking (3d, 3e).

8. Device as claimed in Claim 5, characterised in that the annular concentric markings in each case identify a region of the measurement spot (2a) from which a certain percentage of the energy of the received heat radiation originates.

9. Device as claimed in Claim 5, characterised in that the optical element (5'c) has a focus plane, wherein one circular marking identifies the measurement spot (2a) lying between the optical element and the focus plane and the other marking identifies the measurement spot lying behind the focus plane - when viewed from the optical element.

10. Device as claimed in Claim 1, characterised in that the sighting arrangement has a light source (5a), particularly a laser, for irradiating the diffractive optical system (4).

11. Device as claimed in Claim 1, characterised in that a beam divider (4a, 4'a) which is transparent for the visible light and reflective for the heat radiation emanating from the object of measurement is disposed in the beam path of the sighting arrangement (5).

12. Device as claimed in Claim 2, characterised in that the

optical element is constructed as an annular lens (5'c) and the optical system (4) as an infrared lens (4'b), the annular lens being arranged around the infrared lens.

13. Device as claimed in Claim 1, characterised in that the beam divider (4a) is disposed between the optical element (5c) and the object of measurement (2).

14. Device as claimed in Claim 2, characterised in that the beam divider (4'a) is disposed between the diffractive optical system (4) and the additional optical element (5'c).

Device for temperature measurement

The invention relates to a device for temperature measurement according to the preamble to Claim 1.

Such devices which are known in the art for contactless temperature measurement comprise a detector for receiving heat radiation emanating from a measurement spot on an object of measurement, an optical system for imaging the heat radiation emanating from the measurement spot onto the detector and a sighting arrangement for identifying the position and size of the measurement spot on the object of measurement by means of visible light. A further processing arrangement which converts the detector signal into a temperature indication is also connected to the detector.

In this case the optical system is so designed that at a certain measurement distance for the most part only heat radiation from a certain area of the object of measurement, namely the so-called measurement spot, is focussed onto the detector. In most cases the size of the measurement spot is defined by the area from which 90% of the heat rays focussed onto the detector strike. However, applications are also known in which there is reference to values between 50% and 100%.

The pattern of the dependence of the size of the measurement spot upon the measurement distance depends upon the design of the optical system. A fundamental distinction is made between distant focussing and close focussing. In distant focussing the optical system images the detector into infinity and in close focussing it images it onto the focus plane. In the case of distant focussing it is necessary to deal with a measurement spot which grows linearly with the measurement distance, whereas in close focussing the measurement spot will first of all become smaller with the measurement distance and

after the focus plane will enlarge again if the free aperture of the optical system is greater than the measurement spot in the focus plane. If the measurement spot in the focus plane is greater than the free aperture of the optical system, then the measurement spot is also enlarged with the measurement distance even before the focus plane. Only the increase in the size of the measurement spot is smaller before the focus plane than after it.

In the past various attempts were made to render the position and size of the measurement spot, which is invisible *per se*, visible by illumination. According to JP-A-47-22521 a plurality of rays which originate from several light sources or are obtained by reflection from a light source are directed along the marginal rays of a close-focussed optical system onto the object of measurement. In this way the size and position of the measurement spot for a close-focussed system can be rendered visible by an annular arrangement of illuminated points around the measurement spot. US-A-5,368,392 describes various methods of outlining measurement spots by laser beams. These include the mechanical deflection of one or several laser beams as well as the splitting of a laser beam by a beam divider or a fibre optic system into several single beams which surround the measurement spot.

A sighting system is also known in the art which uses two laser beams to describe the size of the measurement spot. This system uses two divergent beams emanating from the edge of the optical system to characterise a close-focussed system and two laser beams which intersect in the focus point to characterise a close-focussed optical system.

All known sighting arrangements are either only useful for a certain measurement distance or require relatively complex adjustment and are often quite expensive.

The object of the invention, therefore, is to make further developments to the device for temperature measurement according to the preamble to Claim 1 in such a way as to facilitate simple identification of the position and size of the measurement spot independently of the distance.

This object is achieved according to the invention by the characterising feature of Claim 1, in that the sighting arrangement has a diffractive optical system for producing a light intensity distribution with which the position and size of the measurement spot on the object of measurement can be rendered visible.

A diffractive optical system is an optical element, the function of which is based principally upon the diffraction of light waves. In order to produce the diffraction, transverse microstructures which can consist for example of a surface profile or a refractive index profile are provided in the optical element. Diffractive optical elements with a surface profile are also known as so-called holographic elements. The surface patterns are produced for example by exposure of photoresist layers to light and subsequent etching. Such a surface profile can also be converted by electroplating into an embossing printing block with which the hologram profile can be transferred into heated plastic films and reproduced. Thus many holographic elements can be produced economically from one hologram printing block.

The pattern of the diffractive optical system is produced by interference of an object wave with a reference wave. If for example a spherical wave is used as the object wave and a plane wave as the reference wave then an intensity distribution is produced in the image plane which is composed of a point in the centre (0th order), a first intensive circle (first order) and further less intensive circle of greater diameter (higher orders). By screening out of the 0th and the

higher orders an individual circle can be filtered out. A plurality of other intensity distributions which are explained in greater detail below with reference to several embodiments can be produced by other object waves.

Usually approximately 80% of the energy emanating from the light source lies in the patterns produced by the diffractive optical system. The remaining energy is distributed inside and outside the measurement spot.

The light intensity distribution which is produced can be formed for example by a circular marking surrounding the measurement spot or a cross-shaped marking.

Such a device can also be produced economically and only requires a little adjustment work.

Further constructions of the invention are the subject of the subordinate claims and are explained in greater detail below with reference to the description of several embodiments and to the drawings.

In the drawings:

Figure 1 shows a schematic representation of a device according to the invention for temperature measurement according to a first embodiment;

Figures 2a to 2g show schematic representations of various light intensity distributions for identifying the position and size of the measurement spot;

Figure 3 shows a schematic representation of a device according to the invention for temperature measurement according to a second embodiment;

Figure 4 shows a schematic representation of a device according to the invention for temperature measurement according to a third embodiment;

Figure 5 shows a schematic representation of a device according to the invention for temperature measurement according to a fourth embodiment.

Figure 1 shows a first embodiment of a device according to the invention for temperature measurement, comprising

- a) a detector 1 for receiving heat radiation 3 emanating from a measurement spot 2a of an object of measurement 2,
- b) an optical system 4 for imaging the heat radiation emanating from the measurement spot 2a onto the detector 1
- c) and a sighting arrangement 5 for identifying the position and size of the measurement spot 2a on the object of measurement 4 by means of visible light 6.

The sighting arrangement 5 consists essentially of a light source 5a, a diffractive optical system formed for example by a holographic element 5b and an additional refracting and/or reflecting optical element 5c. The light source 5a sends a reference wave 6a onto the holographic element 5b, resulting in a conically opening hologram 6b which is transformed by the optical element 5c so that it forms an intensity distribution 6c which describes the position and size of the measurement spot 2a over all measurement distances.

A laser is advantageously used as the light source 5a for generating the reference wave. However, it is also possible to use a semiconductor light-emitting diode or a thermal light

source. When a thermal light source is used a filter is advantageously provided in order to reduce the chromatic aberrations.

The optical system 4 is formed by a dichroic beam divider 4a and an infrared lens 4b. The heat radiation 3 emanating from the measurement spot 2a first of all reaches the beam divider 4a which deflects the heat radiation, i.e. the infrared radiation, by 90° and delivers it to the infrared lens 4b.

Since the beam divider 4a must of necessity lie in the beam path of the sighting arrangement 5 it is constructed as a dichromatic beam divider which is reflective for the heat radiation emanating from the measurement spot 2a and transparent for the visible light of the sighting arrangement 5.

The size of the marking to be produced depends essentially upon two parameters, namely the measurement distance and the desired accuracy of measurement. The accuracy of measurement results from the percentage of the rays emanating from the measurement spot and focussed onto the detector. The area of the measurement spot can for example be defined by the fact that 90% of the emanating radiation reaches the detector. However, depending upon the application this percentage can also be changed.

The optical element 5c which is adapted to the optical system 4 is provided in order to ensure that in each measurement distance the marking produced for identifying the measurement spot has the correct size for the desired accuracy of measurement.

Figures 2a to 2g show light intensity distributions such as might be produced on the object of measurement 2 for identifying the measurement spot 2a. Figures 2a to 2d show

annular markings which substantially outline the measurement spot 2a. In this case the markings can be configured as in Figures 2a and 2c as a closed circle 3a or in Figures 2b and 2d as a broken circle 3b. It may also be advantageous to represent the centre of the measurement spot by a further marking 3c, for example in the form of a dot.

In Figures 2e and 2f the light intensity distributions are represented as cross-shaped markings 3d and 3e respectively. In this case the point of intersection represents the centre of the measurement spot 2a and the four corner points represent the outer limits thereof.

A very advantageous light intensity distribution is represented in Figure 2g in the form of a plurality of concentric circles 3f, 3g, 3h. In this case each circle represents a region of the measurement spot 2a from which a certain percentage of the energy of the received heat radiation originates. Thus for example the inner circle 3f could represent the region of the measurement spot from which 90% of the energy striking the detector originates. The second ring 3g represents an energy value of 95% and the third ring 3h would correspond to an energy value of 99%. With the aid of such a light intensity distribution the user can recognise the level of accuracy with which he can measure objects of a certain size.

A further device according to the invention for temperature measurement is represented in Figure 3. The same reference numerals are used in this case for the same components. This second embodiment differs from the first one essentially in the design of the optical system 4 and the optical element 5'c of the sighting arrangement 5. In Figure 3 the optical element 5'c is constructed as an annular lens and accordingly is designed to produce a light intensity distribution according to Figures 2a to 2d. The infrared lens 4'b is

arranged so that it is surrounded by the annular lens 5'c. The detector 1 is then provided between the holographic element 5b and the infrared lens 4'b.

Such an arrangement has the advantage that a beam divider can be omitted. However, a somewhat more complicated fixing of the detector must be accepted, since the conically opening hologram 6b must not be restricted thereby.

In the third embodiment illustrated in Figure 4 the problem of mounting the detector 1 is circumvented by providing the beam divider 4'a between the holographic element 5b and the arrangement consisting of the annular lens 5c and the infrared lens 4'b. Thus the heat radiation emanating from the measurement spot 2a is focussed first of all by the infrared lens 4'b onto the beam divider 4'a and is there deflected by 90° onto the detector 1.

Whereas all the previously described embodiments related to distant-focussed systems, an embodiment is shown in Figure 5 in which the shape of the measurement spot of a close-focussed system can be rendered visible with the aid of a diffractive optical system. In this case the measurement plane, i.e. the object of measurement 2, lies directly in the focus plane of the optical system 4. In each case two rays 3i, 3k delimiting the infrared beam are shown in the drawing. The ray 3i extends from the upper edge of the infrared lens 4'b to the upper edge of the measurement spot 2a or from the lower edge of the infrared lens 4'b to the lower edge of the measurement spot. By contrast, the ray 3k extends from the lower edge of the infrared lens 4'b to the upper edge of the measurement spot 2a or from the upper edge of the infrared lens 4'b to the lower edge of the measurement spot.

The optical element 5'c of the sighting arrangement 5 is designed so as to produce two intensity cones 6d and 6e which

substantially follow the course of the marginal rays 3k and 3i. In this case the intensity cone 6e describes the size of the measurement spot as far as the focus plane and the intensity cone 6d describes the divergent measurement spot after the focus plane.

A disadvantage of this embodiment is that the intensity cone 6d extends inside the marginal ray 3k, whilst the intensity cone 6e extends outside the marginal ray 3i. However, this disadvantage can be overcome by another design of the refracting and/or reflecting optical element 5'c.

In the embodiment according to Figure 5 the light intensity distribution could advantageously be formed by two circular concentric markings, wherein one circular marking identifies the measurement spot lying between the optical element 5'c and the focus plane and the other marking identifies the measurement spot lying behind the focus plane - when viewed from the optical element.

Abstract

The invention relates to a device for temperature measurement. The heat radiation emanating from a measurement spot on an object of measurement is imaged by an optical system onto a detector. A sighting arrangement is also provided which has a diffractive optical system by which a light intensity distribution is produced which corresponds to the position and size of the measurement spot on the object of measurement.

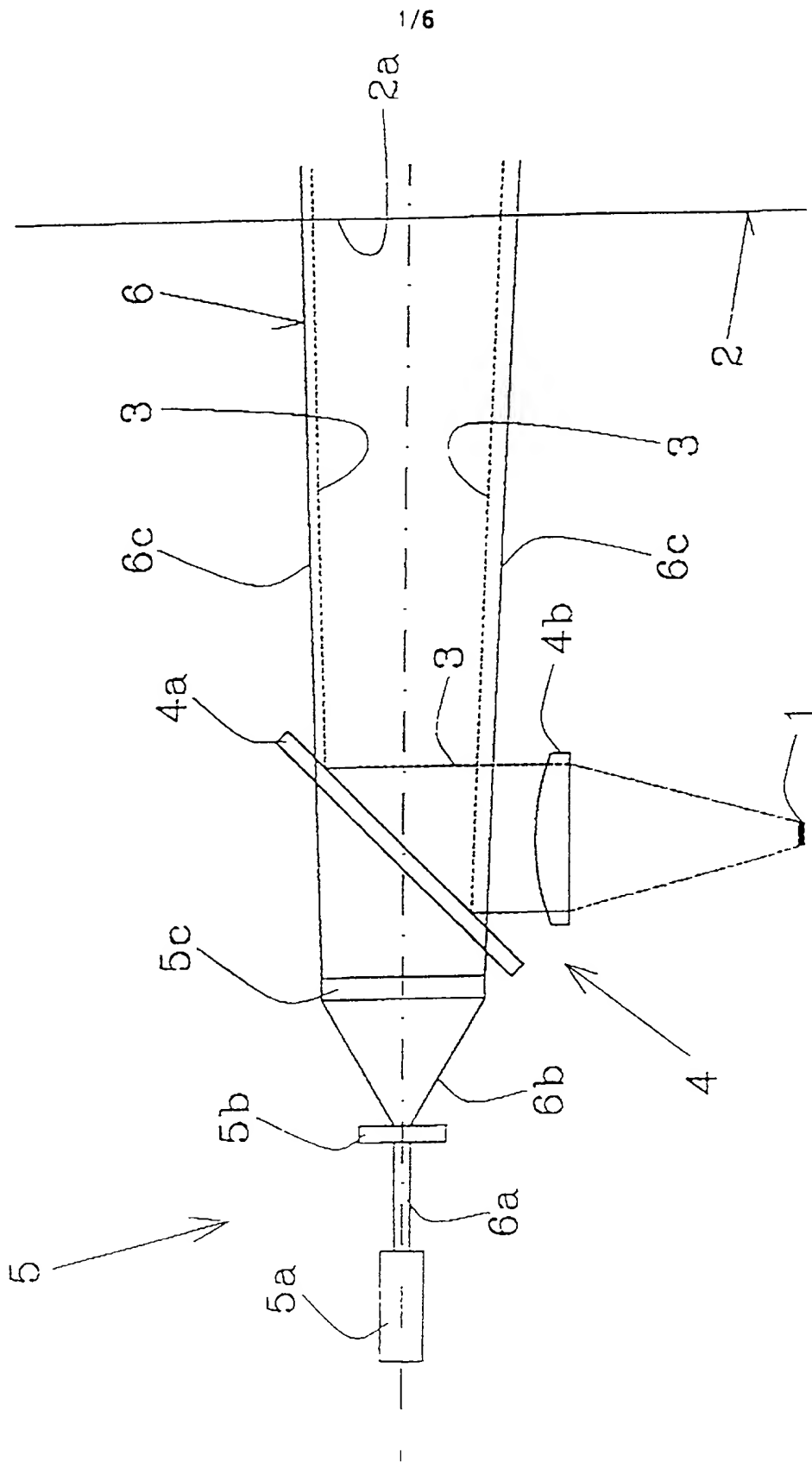


Fig. 1

Fig. 2a

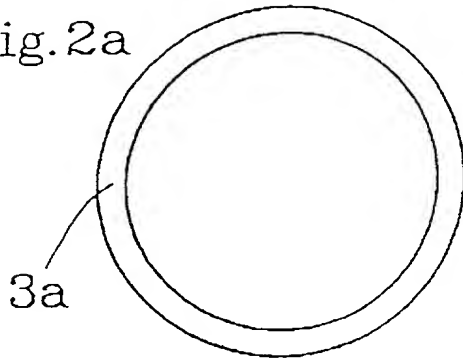


Fig. 2b

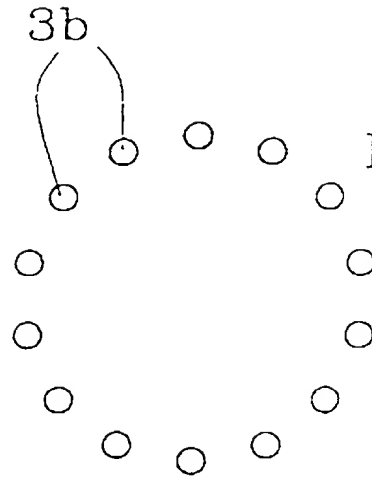


Fig. 2c

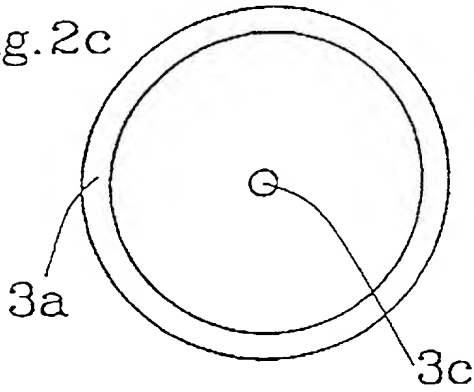


Fig. 2d

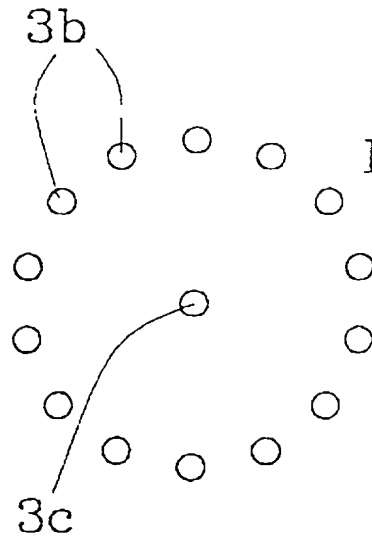


Fig. 2e

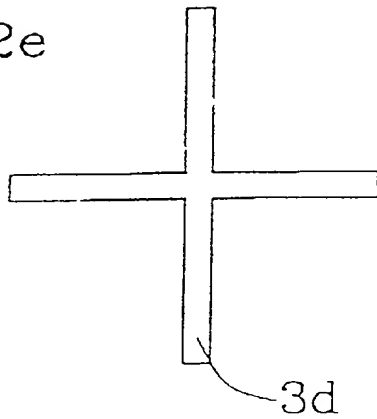
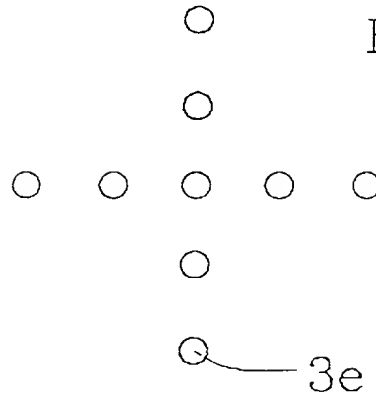


Fig. 2f



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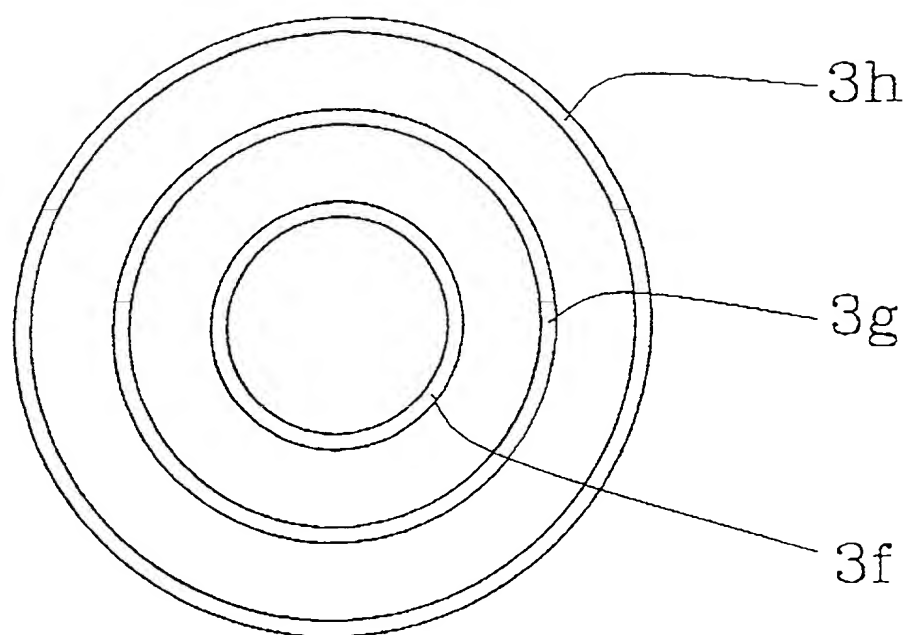
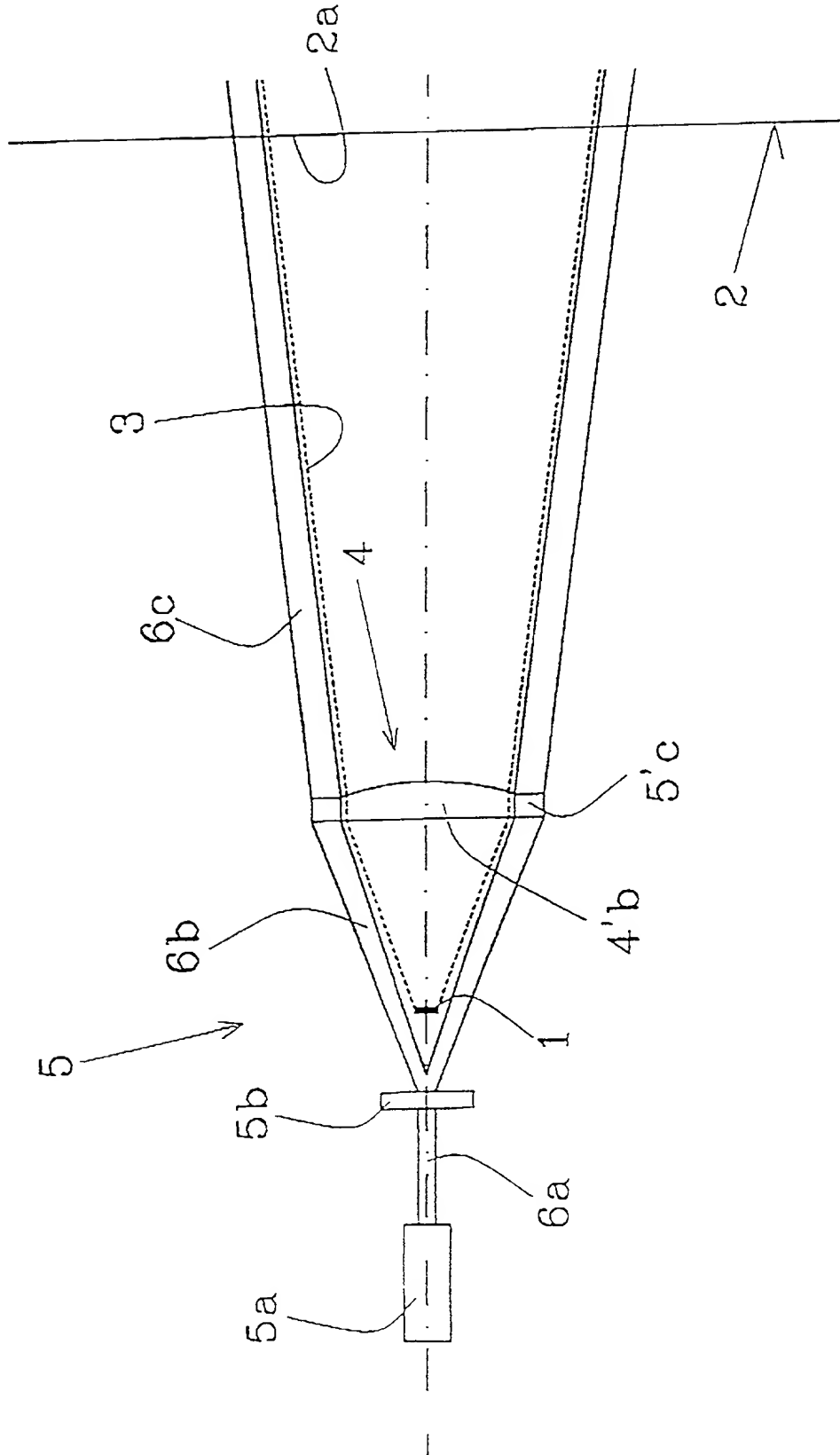


Fig. 29

4/6



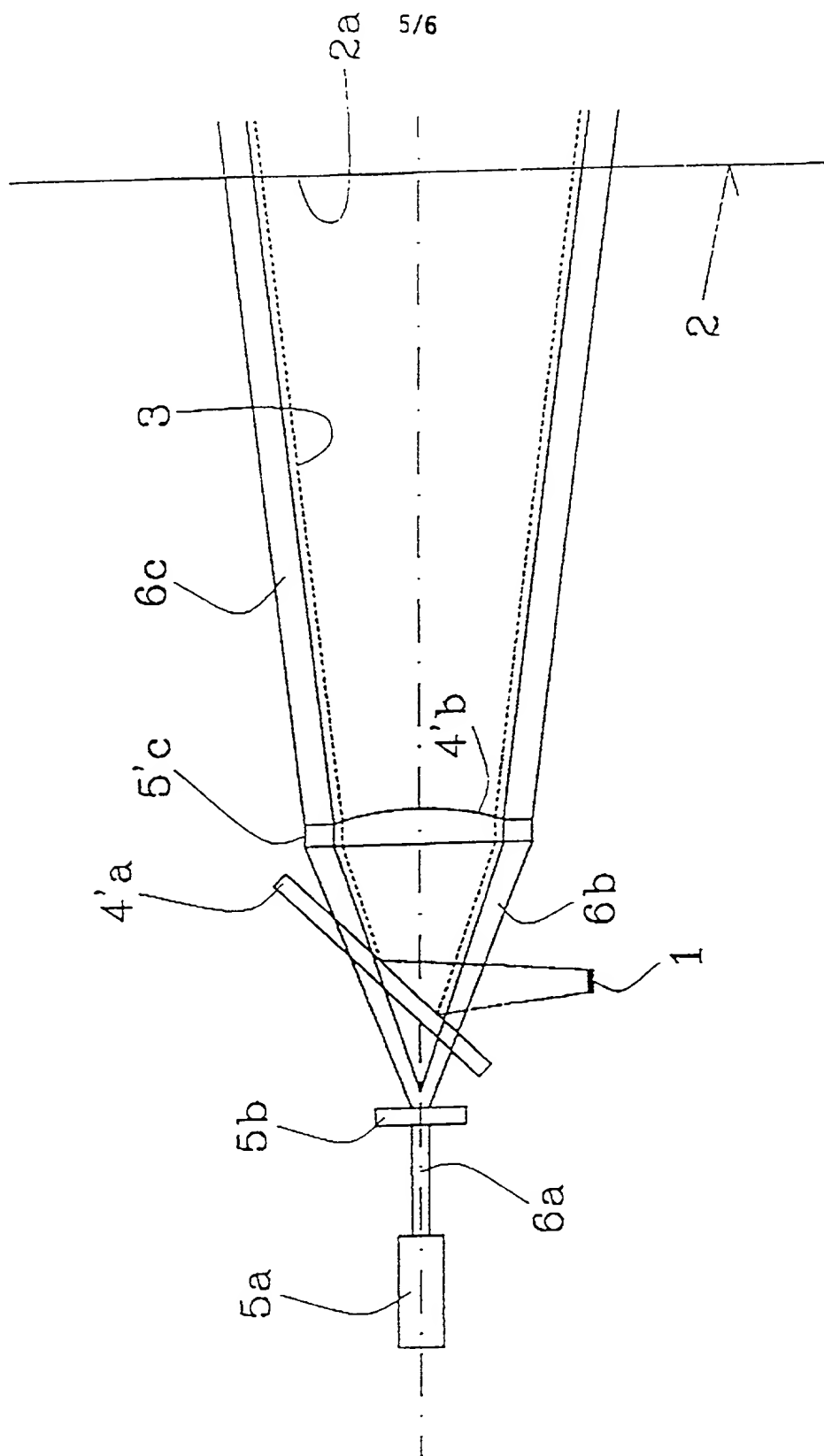


Fig. 4

6/6

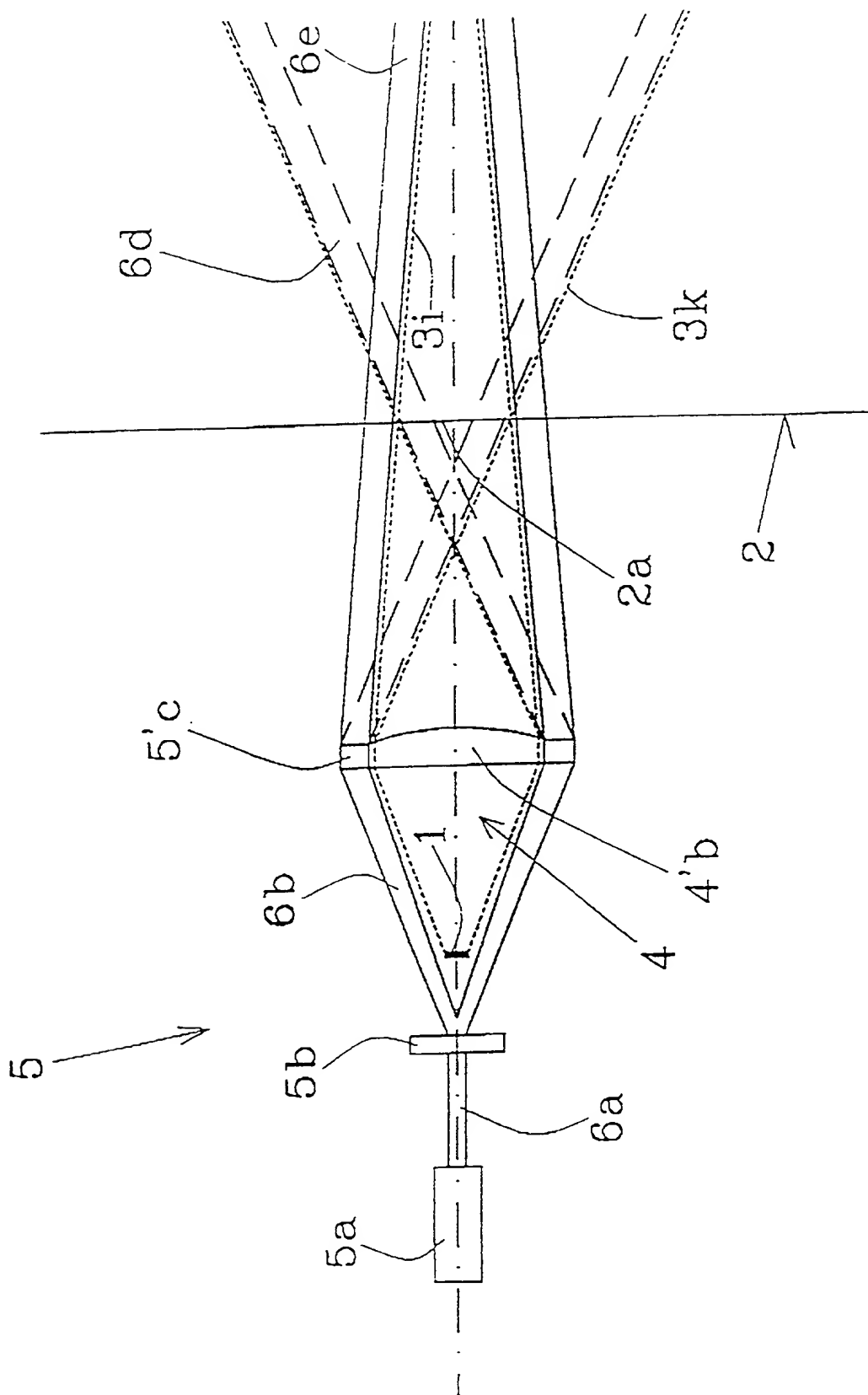
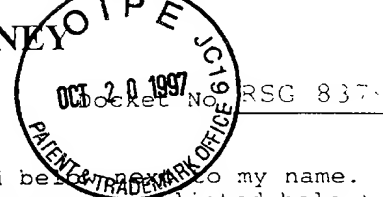


Fig. 5

DECLARATION AND POWER OF ATTORNEY



As a below named inventor, I hereby declare that:

- (a) My residence, post office address and citizenship are as stated below and known to my name.
 (b) I believe I am the original, first and sole inventor (if only one name is listed below) or an original, first and joint inventor (if plural names are listed below) of the subject matter which is claimed and for which a patent is sought on the invention entitled _____

TEMPERATURE-MEASUREMENT INSTRUMENT WITH DIFFRACTIVE OPTICS

the specification of which

(check one) ☐ is attached hereto.

☒ was filed on 26/July/1996, as Application Serial No. PCT/EP96/00330, and was amended on _____ (if applicable).

- (c) I hereby state that I have reviewed and understand the contents of the above identified specification, including the claims, as amended by any amendment referred to above.
 (d) I acknowledge the duty to disclose information which is material to patentability as defined in Title 37, Code of Federal Regulations, §1.56 (a).
 (e) I hereby claim foreign priority benefits under Title 35, United States Code, §119 of any foreign application(s) for patent or inventor's certificate(s) listed below and have also identified below any foreign application for patent or inventor's certificate having a filing date before that of the application on which priority is claimed:

Prior Foreign Application(s)		Priority Claimed
<u>195 28 590.5</u>	<u>DE-Germany</u>	<u>03/Aug/1995</u>
(Number)	(Country)	(Day/Month/Year filed)
		<input checked="" type="checkbox"/> Yes <input type="checkbox"/> No
		<input type="checkbox"/> Yes <input type="checkbox"/> No

(f) I hereby claim the benefit under Title 35, United States Code, §119 (e) or §120 of any United States application(s) listed below and, insofar as the subject matter of each of the claims of this application is not disclosed in the prior U.S. application in the manner provided by the first paragraph of Title 35, U.S. Code, §112, I acknowledge the duty to disclose material information as defined in Title 37, Code of Federal Regulations, §1.56 (a) which occurred between the filing date of the prior application and the national or PCT international filing date of this application:

(Application Ser. No.)	(Filing Date)	(Status-patented, pending, abandoned)
------------------------	---------------	---------------------------------------

I hereby appoint the following attorney(s) to prosecute this application and transact all business in the Patent and Trademark Office connected therewith:

E.J. Biskup	- 18,987
J.C. Evans	- 20,124
R.W. Hoffmann	- 33,711
J.P. Moran	- 20,941
R.L. Stearns	- 36,937

R.L. Farris	- 25,112
J.F. Learman	- 17,069
S.L. Permut	- 28,388
J.D. Stevens	- 35,691

P.J. Ethington	- 17,299
F.J. Fodale	- 20,824
J.K. McCulloch	- 17,452
O.E. Perry	- 19,969
C.R. White	- 20,494

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Saginaw, Michigan 48603

DIRECT TELEPHONE CALLS TO:

John K. McCulloch
 (517) 799-5300

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

Signature _____

Date: October 6, 1997

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 Residence: Berlin, Germany
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 Country: Federal Republic of Germany
 Citizenship: German
 P.O. Address: Kuckhoffstrasse 55
13156 Berlin, Germany

Signature _____

Date:

Full Name:
 Residence:
 City, State, Zip:
 Country:
 Citizenship:
 P.O. Address: